

**WE CLAIM:**

1. A method for fabricating high light extraction  
5 photonic devices, comprising:  
    growing an epitaxial semiconductor device structure  
    on a substrate, said epitaxial semiconductor structure  
    and substrate comprising an emitter adapted to emit light  
    in response to a bias;  
10      flip-chip mounting said emitter on a submount such  
    that said epitaxial semiconductor device structure is  
    sandwiched between said submount and said substrate, and  
    etching said substrate off said epitaxial  
15      semiconductor device by utilizing an etch environment  
    that etches said substrate substantially faster than said  
    epitaxial semiconductor structure.
2. The method of Claim 1, wherein said epitaxial  
semiconductor structure comprises a Group-III nitride  
semiconductor material.
3. The method of Claim 1, wherein said substrate  
comprises a monocrystalline material.
4. The method of Claim 1, wherein said substrate  
comprises monocrystalline silicon carbide (SiC).
5. The method of Claim 1, wherein said etch environment  
comprises a reactive ion etch.

6. The method of Claim 1, wherein said etch environment comprises nitrogen trifluoride ( $\text{NF}_3$ ).
7. The method of Claim 1, further comprising depositing a first mirror layer on said epitaxial semiconductor structure opposite said substrate structure prior to said flip chip mounting of said emitter, said mirror  
5 sandwiched between said epitaxial semiconductor structure and said submount after said flip chip mounting.
8. The method of Claim 7, wherein said first mirror layer comprises a reflective metal.
9. The method of Claim 7, wherein said first mirror layer comprises a distributed Bragg reflector (DBR) comprising a plurality of alternating layer pairs of dielectric material.
10. The method of Claim 9, wherein each of said layer pairs comprise a layer of silicon dioxide ( $\text{SiO}_2$ ) and a layer titanium dioxide ( $\text{TiO}_2$ ), or a layer of silicon dioxide ( $\text{SiO}_2$ ) and a layer of tantalum pentoxide ( $\text{Ta}_2\text{O}_5$ ),  
5 the thickness of said pairs of layers equally a approximately a quarter of said wavelength of said emitted light.
11. The method of Claim 9, wherein said layer pairs repeat two to four times.

12. The method of Claim 7, wherein said first mirror layer comprises an epitaxial DBR comprising a plurality of alternating layer pairs of epitaxial material.

13. The method of Claim 12, wherein each of said alternating layer pairs comprises a layer of gallium nitride (GaN) and a layer of aluminum nitride (AlN), or a layer of gallium nitride (GaN) and layer of an alloy of aluminum nitride ( $\text{Al}_x\text{X}_y\text{N}$ ), said alternating layer pairs having a thickness approximately equal to a quarter of said wavelength of said emitted light.

14. The method of Claim 12, wherein said pairs of layers repeats eight to twelve times.

15. The method of Claim 1, wherein said submount comprises one of the group consisting of monocrystalline silicon carbide (SiC), a silicon substrate and glass.

16. The method of Claim 1, further comprising depositing a second mirror layer on said epitaxial semiconductor structure after said substrate has been etched, said second mirror layer arranged such that said epitaxial semiconductor structure is sandwiched between said submount and said second mirror layer.

17. The method of Claim 16, wherein said second mirror layer comprises a reflective metal.

18. The method of Claim 16, wherein said second mirror layer comprises a distributed Bragg reflector (DBR)

comprising a plurality of alternating layer pairs of  
5 dielectric material.

19. The method of Claim 18, wherein each of said layer pairs comprise a layer of silicon dioxide ( $\text{SiO}_2$ ) and a layer titanium dioxide ( $\text{TiO}_2$ ), or a layer of silicon dioxide ( $\text{SiO}_2$ ) and a layer of tantalum pentoxide ( $\text{Ta}_2\text{O}_5$ ),  
5 the thickness of said layer pairs equal to approximately a quarter of said wavelength of said emitted light.

20. The method of Claim 18, wherein said layer pairs repeat two to four times.

21. The method of Claim 16, wherein said second mirror layer comprises an epitaxial DBR comprising a plurality of alternating layer pairs of epitaxial material.

22. The method of Claim 21, wherein each of said alternating layer pairs comprises a layer of gallium nitride ( $\text{GaN}$ ) and a layer of aluminum nitride ( $\text{AlN}$ ), or a layer of gallium nitride ( $\text{GaN}$ ) and layer of an alloy of  
5 aluminum nitride ( $\text{Al}_x\text{X}_y\text{N}$ ), said alternating layer pairs having a thickness approximately equal to a quarter of said wavelength of said emitted light.

23. The method of Claim 21, wherein said pairs of layers repeats eight to twelve times.

24. The method of Claim 1, wherein growing an epitaxial semiconducting structure comprises:

growing a first epitaxial semiconductor layer on said substrate, and

- 5       growing a second epitaxial semiconductor layer on said first epitaxial semiconductor layer, such that said first semiconductor layer is sandwiched between said substrate and said second semiconductor layer.

25. The method of Claim 24, wherein growing an epitaxial semiconducting structure comprises growing thin doped layers and forming a resonant cavity light emitting diode.

26. A method for fabricating high light extraction photonic devices, comprising:

growing an epitaxial semiconductor structure on a substrate;

- 5       depositing a first mirror layer on said epitaxial semiconductor structure such that said epitaxial semiconductor structure is sandwiched between said first mirror layer and said substrate;

- removing said substrate from said epitaxial  
10 structure by introducing an etch environment to said substrate; and

- depositing a second mirror layer on said epitaxial semiconductor structure such that said epitaxial semiconductor structure is sandwiched between said first  
15 and second mirror layers.

27. The method of claim 26, wherein said etch environment etches said substrate substantially faster than said epitaxial semiconducting structure, etching off

substantially all of said substrate without etching off  
5 substantially any of said epitaxial semiconducting  
structure.

28. The method of claim 26, wherein said epitaxial  
semiconductor structure is adapted to emit light in  
10 response to an electrical signal.

29. The method of Claim 26, wherein said epitaxial  
semiconductor structure comprises a Group III nitride  
semiconductor material.

30. The method of Claim 26, wherein said substrate  
comprises monocrystalline silicon carbide (SiC).

31. The method of Claim 26, wherein said etch  
environment comprises a reactive ion etch.

32. The method of Claim 26, wherein said etch  
environment comprises nitrogen trifluoride (NF<sub>3</sub>).

33. The method of Claim 26, wherein either of said first  
or second mirror layers comprise a reflective metal.

34. The method of Claim 26, wherein said either first or  
second mirror layer comprise distributed Bragg reflector  
(DBR) mirror having alternating layer pairs of dielectric  
material.

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35. The method of Claim 34, wherein each of said layer  
pairs comprise a layer of silicon dioxide (SiO<sub>2</sub>) and a

layer titanium dioxide ( $\text{TiO}_2$ ), or a layer of silicon dioxide ( $\text{SiO}_2$ ) and a layer of tantalum pentoxide ( $\text{Ta}_2\text{O}_5$ ).

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36. The method of Claim 26, wherein either of said first or second mirror layers comprise an epitaxial DBR mirror alternating layer pairs of epitaxial material.

37. The method of Claim 36, wherein each of said alternating layer pairs comprises a layer of gallium nitride ( $\text{GaN}$ ) and a layer of aluminum nitride ( $\text{AlN}$ ), or a layer of gallium nitride ( $\text{GaN}$ ) and layer of an alloy of  
5 aluminum nitride ( $\text{Al}_x\text{Ga}_{1-x}\text{N}$ ).

38. The method of claim 26, further comprising flip chip mounting said first mirror layer, epitaxial semiconductor structure and substrate combination on a submount after depositing said first mirror, such that said first mirror  
5 layer is adjacent to said submount and said first mirror layer and epitaxial semiconductor structure is sandwiched between said submount and substrate.

39. The method of Claim 38, wherein said submount  
10 comprises one of the group consisting of monocrystalline silicon carbide ( $\text{SiC}$ ), a silicon substrate and glass.

40. A resonant cavity light emitting diode (RCLED), comprising:

a thin film epitaxial semiconductor structure;

5 a first mirror layer on one surface of said epitaxial semiconductor structure;

a second mirror layer on another surface of said epitaxial semiconductor structure such that said epitaxial semiconductor structure is sandwiched between said first and second mirrors, said second mirror layer  
10 being less reflective than said first mirror layer;

a submount, said epitaxial semiconductor structure with its said first and second mirrors mounted on said submount, said first mirror layer being adjacent to said submount and said second mirror layer being the primary  
15 emitting surface.

41. The RCLED of claim 40, wherein said epitaxial semiconductor device emits light and has a thickness to provide a resonant cavity for said light.

20 42. The RCLED of claim 40, wherein said epitaxial semiconductor device comprises two layers of semiconductor material that are oppositely doped.

25 43. The RCLED of claim 40, wherein said epitaxial semiconductor device comprises an semiconductor active region sandwiched between two oppositely doped layers.

30 44. The RCLED of claim 40, wherein said either said first or second mirror layer comprise a metal.



45. The RCLED of claim 40, wherein said first or second mirror layers comprise a distributed Bragg reflector (DBR)

5 46. A method for removing a silicon carbide substrate from a Group-III nitride epitaxial semiconductor material, comprising:

growing a Group-III nitride epitaxial semiconductor material on a silicon carbide substrate;

10 introducing an etch environment to said silicon carbide substrate, said etch environment etching silicon carbide faster than said Group-III nitride epitaxial material such that said etching substantially stops after said silicon carbide is etched off.

15 47. The method of Claim 46, wherein said etch environment comprises a reactive ion etch.

20 48. The method of Claim 46, wherein said etch environment comprises nitrogen trifluoride (NF<sub>3</sub>). Reactive ion etch